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AN INQUIRY INTO THE USE OF MULTIPLE DISCRIMINANT ANALYSIS IN VOCATIONAL GUIDANCE

by

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The undersigned hereby certify that they have read and recommended to the Faculty of Graduate Studies, a thesis entitled, "An Inquiry Into the Use of Multiple Discriminant Analysis in Vocational Guidance", submitted by Robert Smilanich in partial fulfillment of the requirements for the degree of Master of Education.

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ABSTRACT

It was the purpose of this study to show how the vocational guidance counsellor may make use of linear equations in the placement of students into programs and in identifying and assisting those students most likely to experience difficulty once in a program. Students who were either recommended or not recommended to continue study in four different vocational areas were used in the sample. The subtests of the Dailey Technical and Scholastic Test were used as the variables in determining a discriminant function for each group.

Given a number of observations for each of a number of individuals who may be classified into one or more mutually exclusive groups, the application of discriminant analysis permits the development of equations which may be used to optimize classification of future groups of observations. The relative contribution of each variable to the classification can be determied and used to identify dimension along which optimum separation occurs.

On the basis of the discriminant scores obtained for each individual, seventy-six percent of the electricity students would have been placed in the same category as that recommended beforehand by the teacher. Of the forty automotive students, twenty-six of the placements were in agreement with the teacher's recommendation. The apparent lack of validity of the tests used for predictive or classification purposes in welding and machine shop was observed. Whereas in the welding group fifty-eight percent of the predictions were in agreement with the teacher's recommendation, there was disagreement on seventy-three percent of the machine shop placements.

The uses of meaningful critical scores were found to be many. The comparison between the students' discriminant scores and the critical score established for a program could be used in discussing program selection. For students in a program and experiencing difficulty, the size of the vector weight products in their discriminant function may suggest a course of action to the counsellor. The relative weights of the vectors was also found to contain value in determining course prerequisites and in examining assessment practices.

It was suggested that further research was needed in three major areas: in the identification and description of specific types of behavior critical to task performance, in the development of tests to measure these job elements, and in the development of a continuous program of evaluation to compare the efficiency of proposed programs to that of existing programs.

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CHAPTER I

FORMULATION AND INTRODUCTION OF THE PROBLEM

Introduction

At no other time have governments been so actively concerned with discovering effective methods for the identification, development and utilization of their manpower resources. Since the passing of the Vocational Education Act by the Federal Government in 1961, in Alberta alone, in excess of $170,000,000 has been allotted to the construction and staffing of vocational schools. As a result, traditional programs have been enriched and others created so that the needs of the ever-increasing high school population may be satisfied.

However, the mere provision for differentiated curricula is not sufficient to insure desired goals. It is becoming increasingly obvious that students must be assisted in understanding and assessing their abilities in order that full benefit may be gained from such innovations. Determining the means through which this shall be done poses one of the most complex yet vital areas of concern for guidance personnel today.

Flanagan et al (1962) suggest that just as the employer who assigns a $10,000 a year engineer to design specifications that a $6,000 a year draftsman could do equally well is wasting both talent and money, the guidance counsellor who has no tools for predicting whether a student would have greater success in electronics or automotives is falling short of performing a service much needed by the student, industry and the nation. Flanagan further adds that:

> . . . the national waste (abuse and misuse) of human resources is

> appalling. Anyone assigning a dollar value to the squander of human talents will be wide of the mark and there is no way to begin to estimate the additional cost in frustration and unhappiness for the individual whose time and effort go into activities which bring them little satisfaction.

In a recent report published by the Research and Development Division of the American College Testing Program which studied the relationship between college grades and adult achievement, it was concluded that all evidence to date suggests that "college grades bear little or no relationship to any measure of adult accomplishment (p. 1)." It further suggests that there is good reason for believing that academic achievement and other types of student growth are relatively independent. The importance of such findings can only be fully realized when one considers the great number of decisions made using college grades as the major criterion.

What are the implications of this study for educators in Alberta Vocational Schools? A review of current procedures makes it all too obvious that grades allotted not only determine the programs available to the student while in high school, but also determine the degree and type of further educational opportunities that will become available. The situation becomes even more alarming when it is realized that no provincial or even local norms are available for the various vocational programs so that recommendations may be made on a more empirical basis.

In the report cited above, it was recommended that evaluations be made on the basis of multiple considerations and that a profile of student growth and potential be substituted for the present transcript of grades. Such a profile suggests the need for data on interests, work habits, personality factors, measured aptitudes and as many other aspects of the

students' growth as are possible. Only after such information becomes available will assessment practices be progressing in the direction of certainty and away from chance.

Purpose of the Study

The Alberta grade ten vocational program is primarily of an exploratory nature providing students with the opportunity to investigate the various technical areas offered at the grade eleven level. It is believed that by exposing the students to a sampling of both the theory and the practical skills involved in the senior courses that they will arrive at a more realistic assessment of their own abilities in terms of course requirements for the following year.

On the basis of their grade ten performance, the students are either recommended or not recommended for further study in a particular area. Thus, it is being assumed that those who do well at the grade ten level will also do well in the senior course. Those who are not recommended are not likely to have the opportunity to attempt the senior program.

It is strongly felt that although in any group it may be possible to differentiate those most likely to succeed from those least likely, there are many students who cannot be so easily categorized. Furthermore, as was recommended earlier, such assessments must be made only after much data has been considered and the relative contribution of each determined.

It is the purpose of this study to show how, through use of the discriminant function, patterns or combinations of traits may be established which distinguish certain groups. More specifically, it is

proposed that:

1. Through use of the Dailey Technical and Scholastic Test and multiple discriminant analysis, critical scores may be determined which, when applied to an individual's discriminant score, suggest which group (recommended - not recommended) he is most likely a member.
2. Information can be procured from discriminant scores and vector weights that would be of assistance to the counsellor in identifying student difficulties.

CHAPTER II

REVIEW OF THE LITERATURE

Use of Tests in Vocational Guidance

Super (1962, p. 2) describes vocational guidance as the "process of helping the individual ascertain, accept, understand, and apply the relevant facts about himself to the pertinent facts about the occupational world which are ascertained through incidental and planned exploratory activities."

Implicit in this definition is the assumption that differing levels and combinations of abilities are required for proficiency in various jobs. Thus, by systematically matching the individual's high aptitudes with the special requirements of the jobs which he is prepared to enter, substantial gains can be made in the effective use of manpower resources (Flanagan 1962).

Although there is no general consensus as to the role of diagnostic techniques in vocational guidance, studies by Seeman and McGowan (1962, p. 495) have clearly indicated that most clients seeking educational and vocational guidance anticipate that tests will play an important part in the process and expect tests to provide them with information they need. Regardless of the position taken by individual counsellors, most will agree to the use of tests when the needs of the client clearly indicate that tests may provide the added information required to make the best possible decision. To ensure the effective employment of tests, however, Goldman (1962, p. 13) warns that they should be used as an adjunct to skillful interviewing so that test scores may be interpreted in the light

of other background information about the individual.

Current rationale in the use of aptitude tests in vocational guidance is indicated by the following principles proposed by Flanagan (1963, p. 115):

1. The multidimensional aptitude test approach is essential to the effective use of manpower resources.
2. In order for students to make effective use of their talents they must have a comprehensive and precise description of these talents.
3. The individual should be described in terms of the extent to which he has the specific abilities required for a given occupation, or the necessary aptitudes to develop these abilities.
4. The descriptive categories should be as independent of each other as possible.
5. Each descriptive category should be studied along with others in the set to determine the extent to which it includes unique aptitudes or abilities not included in a combination of the other categories.
6. Efficient statistical procedures should be used to determine the relative appropriateness of the individual's talents for various occupations which he might choose.

The Meaning of Aptitude

As research in the area of mental measurement becomes more sophisticated, less distinction is being made between the terms aptitude,

intelligence and achievement. Psychometricians are finding it increasingly difficult to differentiate between innate and acquired components of measured abilities. These can only be appraised as they are reflected in an individual's performance in test situations. This performance is conditioned by his experience and learning (Adams, 1957).

Aptitude is defined in the Dictionary of Psychology as "a conditioned set of characteristics regarded as symptomatic of an individual's ability to acquire, with training, some usually specific knowledge, skill or set of responses such as ability to speak a language or to produce music (Adams, 1957, p. 86)." Super suggests that aptitude "is not necessarily an entity but rather a constellation of entities" and that the set of characteristics which enables one person to learn something may be different from that which enables another person to learn the same thing (Super, 1962, p.27). Hahn and MacLean refer to aptitudes as latent potentialities, undeveloped capacities to acquire abilities and skills and to demonstrate achievements.(Froehlich, 1959, p. 118). Remmers states that aptitudes are simply "present traits considered as predictors of future achievement" (Adams, 1957, P.87). Along similar lines, Torgenson, Wood and Adams (p. 88) suggest:

> that the real distinction between achievement and aptitude is in the purpose for which testing took place . . . whether the point of view is backward looking or forward looking, whether the concern is with the pupil's past or with his future.

This somewhat more global approach to aptitudes has resulted in less use of such terms as intelligence and I.Q. in favor of words such as scholastic aptitude that call attention to the contribution of the individual's environment.

In a study presently being conducted, the designers of Project Talent have elected to employ the broad term "talent" and define it as a unique pattern of "potentials" for learning to perform various types of activities ranging from learning to paint or to prepare food to telling stories (Flanagan et al, 1962). Thus, data on intelligence or achievement tests, school grades, performance in exploratory courses or even physical and personal traits can all be interpreted as evidence of a student's aptitude for a given vocation since all have value as predictors of future achievement.

Use of Discriminant Function Analysis

Since its introduction by R. A. Fisher in 1935, the application of discriminant analysis to scholastic problems of a predictive nature has comparatively little precedent. Calia (1960, p. 184) reports that "the usage of discriminant function has been relatively small, if not non-existent in many areas." Tiedeman (1954, p. 415) adds that it is "virtually unused" in the fields of either psychology or education. The most common explanation for its avoidance lies in the "computational drudgery" (School and Society, 1959, p. 324) involved, or, as Garrett (1943, p. 65) explains, "the lack of an account comprehensible to those not especially trained in mathematics."

However, during the past few years, the potential of the discriminant function in psychological and educational research has received increasing emphasis in the literature. Calia (1960, p. 184) refers to it as a "new and powerful research tool in an area (prediction)

that has and will continue to assume increasing importance." Johnson (1953, p. 35) reports that the "development of methods of discriminant analysis open up new promise to the study of educational problems involving classification . Along similar lines, Moonan (1952, p. 281) adds that both psychology and education abound with classification problems which need "to be attacked with these rigorous new techniques." Although discriminant analysis has been used most extensively in agricultural and biological research, Hall (1963, p. 163) concludes that its classification procedures are "particularly relevant to diagnostic, educational and counselling problems" where tests often form the basis for future therapy, training or employment.

Discriminant analysis, in the general case, is designed to determine the group which an individual most closely resembles. Given a number of observations for each of a number of individuals who may be classified into one or more mutually exclusive groups, relative importance of each variable is determined by maximizing the ratio of the variance between groups to variance within the groups. Maximum separation between the groups can then be made on the basis of the compound measurements thus obtained. Thus, as Tiedeman explains, (1951, p. 76) discriminant analysis "takes into account" variability of group means on the "n" variables, variation of individuals about group means on the "n" variables, and interrelationships of the "n" variables. Similarily, Super states that the discriminant function not only provides information on the similarities and differences among groups, but allows the description of individual differences within groups (Super, P. 95). Rulon (Spring Hall, 1964) points out that since

this technique maximizes the between group variance relative to within group variance, it is appropriately used when the question asked has to do with group characteristics but not with the question of relationship to an outside criterion of goodness. The dependent variable is qualitative rather than quantitative. A store clerk is not a good one or a bad one in discriminant analysis; depending upon the categories used, he may be more like a store clerk than mechanic.

Of what advantage would the use of discriminant analysis in test interpretation be compared to the "profile approach" now used extensively in guidance? Tiedeman (1951) suggests that this popular uni-dimensional chart with various scales along that dimension is an entirely inappropriate model of the situation. He suggests that among other weaknesses, such a profile fails to account for the overlapping when comparing a single score to those obtained by two different groups and does not explain the significance of the differences obtained on the various scales. It is suggested that the proper model is in space with a "swarm" of red dots for one group and a "swarm" of blue dots for the other. The question then becomes one of determining whether the new scores in question belong in the set of red dots, the blue dots, in both, or in neither. Such is the approach suggested through use of the discriminant function.

In a discussion of a similar nature, Hall (1957) contends that not until the counsellor knows the optimal combination of scores on all tests for the purpose of contrasting occupational and educational groups will a given battery approach maximum usefulness. Discriminant analysis is such a technique since it is designed to "obtain group differentiation in all

the test variates antecedent to occupational or educational choice " (Hall, p. 557).

Discussing the potential use of discriminant analysis in science education, Anderson (1962) concludes that:

> . . . use of such a technique makes more sense in assigning students to classes than the usual methods employed in "ability" groups. With this technique we have discriminated between known groups and this enables us to assign an individual to a given group with a maximum of error.

It would appear that the utilization of discriminant analysis in other areas of the curriculum holds equally promising results.

Illustrative Applications of the Discriminant Function

The discriminant function has been used most commonly to examine the effectiveness of test batteries or entire testing programs in predicting completion of university or college programs. Little mention to date has been made of the discriminant function being used at the high school level.

Typically, students are given a battery of tests upon entrance into a program. The scores obtained are then compared to the critical scores established on the basis of scores obtained by successful and unsuccessful graduates in preceding years. It is then observed whether the test performance of a given student resembles the performance of the group of successful individuals more closely than it resembles that of another group.

In such a study, Stinson (1959) used four psychological tests to determine a linear discriminant function, a multiple triserial R and cutting scores to be used by counsellors in guiding freshmen enrolled in an orientation course for engineering students. Three groups were

established: those who successfully graduated, those who graduated in some other program, and those who withdrew from university. Thirty subjects randomly selected from each group constituted the sample.

The multiple triserial R was found to be .51, representing a rather substantial relationship between composite test scores and membership in one of the three groups. Standard mathematical procedures were used in solving four simultaneous equations to ascertain appropriate weights for the four variables. The discriminant function determined was:

$v = .00209X_1 + .006168X_2 + .05142X_3 + .010834X_4$, where

$X_1 =$ score on the A.C.E. Psychological Examination,

$X_2 =$ score on the Guilford Zimmerman Aptitude Survey (verbal comprehension),

$X_3 =$ score on the Guilford Zimmerman Aptitude Examination (general reasoning), and

$X_4 =$ score on the Scientific Scale on the Kuder Preference Record.

The discriminant score for each group was found by substituting the mean values of the tests for each of the three groups into the discriminant function. The critical scores were considered to be midway between the predicted discriminant scores and were found to be as follows:

1.86 and above for engineering students,

1.59 - 1.85 for non-engineering students, and

1.58 and below for dropouts.

In a study designed for much the same purpose, Ivanoff, (1961) using a sample of 2012 males and 415 females, hypothesized that there was no significant relationship between academic success (probation - non-probation) during a student's first semester and the data (stanine scores

achieved on the ACE, stanine scores from the Nebraska English Placement Examination, quarter rank in high school graduation, and ratings assigned to the size of high school at time of graduation, and ratings assigned to occupational status of parent) obtained at the time of graduation. An application of Fisher's discriminant analysis demonstrated that the combination of ACE-L, English Placement Score and quarter rank (multiple R of .63) did effectively discriminate male probation students and that the combination of English score and quarter rank (multiple R of .71) did effectively identify female probation students.

The discriminant function is particularly useful in studies such as the above where it is possible that only a small number of the variables with significant difference in means are contributing to the discrimination among the groups while other variables which by themselves provide no means of discrimination may aid considerably when taken in conjunction with the rest.

Jackson (1948) also illustrated that in addition to suggesting group membership, the scaled vector weights of the discriminant function indicate which of the various variables used are the largest contributors to this separation. Using the final grades allotted in a freshman chemistry course as the dependent variable and the scores obtained on the ACE Psychological Examination and the Michigan State College Pre-test (Part I and II) as the independent variables, it was concluded that the linear compound of the three tests distinguished significantly between those students obtaining grades A-B-C and those obtaining D or F. The coefficients also indicated that success in the course was most closely

related to the score on Part I of the Pre-test, less closely related to the score on Part II of the Pre-test and least closely related to the ACE total.

Discriminant analysis has also been used to determine the relative contribution of the various dimensions of a single test battery. Multi-aptitude tests such as the Differential Aptitude Test and the Kuder Preference Record have been used extensively for this purpose. Using the Differential Aptitude Test, Hall (1957) conducted a study designed to determine the extent to which 287 males in six different sub-professional occupational groups could be contrasted or differentiated. Using Fisher's discriminant function, the one best vector which distinguished the groups as much as possible was $V = 0.94X_1 + 0.31X_2 + 0.57X_3 - 0.33X_4 - 0.18X_5 + 1.0X_6 - 0.42X_7 + 0.67X_8$ where:

X_1 = verbal reasoning,
X_2 = numerical ability,
X_3 = abstract reasoning,
X_4 = space relations,
X_5 = mechanical reasoning,
X_6 = clerical speed and accuracy,
X_7 = language usage (spelling), and
X_8 = language usage (sentence).

It was concluded that in terms of general factors, differentiation among the six groups was regarded as a combination of verbal ability as evidenced by the weights assigned to verbal reasoning, language usage (spelling), language usage (sentence) and speed of perception in routine manual tasks in terms of the weights assigned to clerical speed and accuracy.

To demonstrate how discriminant analysis may be used for predictive purposes, Tiedeman and Sternberg (1952) administered the Differential Aptitude Test to a number of grade eight students. The results were not

made available until after they had chosen either the Business or the College Preparatory Curriculum in grade ten. It was found at that time that if the group of 207 pupils had followed advice to enter either the College Preparatory Curriculum if their score was above a determined point, or the business curriculum if their score fell below that point, only thirty-nine students or approximately one-fifth of the sample would have chosen a curriculum different from that which they actually chose. As the authors concluded, ". . . this is not too bad a record for a test that yields only eight scores" (p. 273).

In a similar study, Baggaley (1947) reviewed the scores obtained on the Differential Aptitude Test by 185 Harvard students at the termination of their freshman year to determine whether or not the scores could be of any assistance in detecting a student's academic interests. The students were categorized according to their field of concentration: natural sciences or humanities. A critical score was obtained and it was found that only 13.6 percent of the students in the natural sciences fell below this score and that fourteen percent of the students in the humanities obtained scores higher. The difference between the means of the discriminant functions yeilded a "t" - value of 12.13, significant at the .01 level. On the basis of these results, it was concluded "that the Kuder scores provide a sound basis for differentiating students who propose to concentrate in different academic fields" (p. 427).

On the basis of the investigations reviewed, it would appear that the proposed use of the discriminant function is supported.

CHAPTER III

PROCEDURE -- DESIGN OF STUDY

Sample

The ninety-eight grade ten students selected for the study completed the first three rounds of the General Technical Program at Victoria Composite High School and studied in one or more of automotives, machine shop, electricity or welding. The General Technical Program is an introductory vocational course designed for students interested in later enrolling in one of the regular "twelve-twenty-two" vocational programs. Throughout the year each student has the opportunity to investigate four vocational areas of his choice.

For each area studied the student is given a numerical grading and is assigned to one of three categories: recommended, borderline, or not recommended for the related "twelve-twenty-two" program. It is possible that the scores for a single individual in two or even three areas have been included in the study.

The total number in each area represents approximately seventy-five percent of the total group who will be studying in that particular area. In each vocational area considered, there is a common teacher with common objectives so that a maximum amount of consistency in scoring has been planned for.

The number of students in each category is shown in Table I.

Preparation of Data

The Dailey Technical and Scholastic Test was administered to all students and the results scored manually.

TABLE I

DISTRIBUTION OF SAMPLE BY CATEGORY

Vocational Area	Recommended	Borderline	Not Recommended	Total
Automotives	29	5	11	45
Machine Shop	30	12	7	49
Electricity	21	9	17	47
Welding	26	4	12	42
		TOTAL		153

For each student an I.B.M. card was produced containing his school identification number, the vocational areas studied, category assigned to in each area, mark given for each area and the scores obtained on the subtests and composite scores.

From the original, three additional decks were produced so that a card representing each student in each area was available at any given time.

Treatment of Data

All data was processed on the IBM 7040 at the Department of Computing Science, University of Alberta.

In order to determine those variables (subtests) that would contribute most to the discriminant function, it was necessary to first:

(a) examine the difference between means on each of the seven subtest scores for those recommended and those not recommended in each of automotives, machine shop, electricity and welding. In the program used, sums of squares, mean squares, F-tests and probability of the F-values were calculated.

(b) calculate regression coefficients for each of the vocational areas using the numerical grades allotted as the dependent variable and the subtest scores for Electricity, Electronics, Mechanics, Science, Arithmetic, Algebra, and Vocabulary as the independent variables. Beta weights, the regression constants, tests of significance and a measure of the variance accounted for with the addition of each new variable were

computed. Also, correlation coefficients between the subtest scores and the assigned grades were obtained.

Those variables with the largest difference between means and which in addition accounted for the greatest amount of variance in the regression equations for each vocational area were selected as vectors for the discriminant equation.

To determine the extent to which the subtests and composite scores were independent of each other, intercorrelations were tabulated.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Examination of Group Means and Intercorrelations of Subtests

The Examiner's Manual for the Dailey Vocational Tests report that "the intercorrelations are sufficiently low to justify the use of separate subscales" (p.31) for examinees in the eleventh grade and beyond (N = 591). Only limited evidence to support such a claim is suggested by the present study.

An examination of Table II shows that there is no one subtest that is not substantially correlated with at least one other. Such correlations would suggest that the subscales are not substantially independent of each other and are heavily loaded with a measure of scholastic aptitude. The comparatively lower intercorrelations between Algebra and Arithmetic and the other subtests can possibly be explained on the basis of the two being of a non-verbal nature while the others are predominantly verbal or non-computational.

The high intercorrelations between the Electrical, Mechanical, and Scholastic composite scores and the subtests can be expected since they are combinations of the subtests, some of which are common to more than one. The Electrical score is composed of the Electricity, Electronics, Mechanics, and Science subtests while the Mechanical score is a combination of the Mechanics and Arithmetic subtests. The Scholastic score is comprised of the Arithmetic, Algebra, and Vocabulary subtests.

The means and standard deviations for the electricity students are shown in Table III. It can be seen that those in the "recommended"

TABLE II

SUBTEST AND COMPOSITE SCORE INTERCORRELATIONS FOR DISCRIMINANT FUNCTION

SAMPLE

	Ely.	Eln.	Mech.	Science	Arith.	Algebra	Vocab.	Elect.	Mechan.	Schol.	Total
Electricity		0.514	0.497	0.539	0.583	0.489	0.436	0.794	0.636	0.628	0.779
Electronics			0.418	0.385	0.216	0.143	0.387	0.716	0.362	0.297	0.558
Mechanics				0.466	0.464	0.242	0.549	0.833	0.848	0.551	0.759
Science					0.452	0.393	0.612	0.742	0.546	0.613	0.742
Arithmetic						0.564	0.460	0.556	0.855	0.865	0.773
Algebra							0.290	0.393	0.483	0.708	0.598
Vocabulary								0.645	0.593	0.764	0.768
Elect.									0.810	0.674	0.918
Mechan.										0.840	0.901
Schol.											0.911

TABLE III

SUBTEST MEANS AND STANDARD DEVIATIONS FOR

ELECTRICITY STUDENTS

SUBTEST	GRAND MEAN N = 38	S. D.	RECOM. MEAN N = 21	NOT RECOM. MEAN N = 17
Electricity	9.37	2.38	10.286	8.235
Electronics	4.16	2.70	4.286	4.000
Mechanics	17.45	5.21	19.333	15.118
Science	9.76	2.33	10.429	8.941
Arithmetic	22.18	4.48	23.762	20.235
Algebra	8.00	2.87	9.048	6.706
Vocabulary	16.71	4.76	18.048	15.059

group score consistantly higher on all subtests that those in the "not-recommended" group. Since the test purports to "reflect technical and academic knowledge as well as aptitude required for development of competence in a variety of occupations and educational programs" (Examiner's Manual, p.:3) considering the high intercorrelations it must be concluded that either those who have been recommended for electricity possess more knowledge and aptitude for all seven areas tested or that there is a measure of scholastic aptitude common to all subtests and that those students recommended possess this trait to a greater extent than those not recommended.

From Table IV it is evident that the score obtained by the auto students on all subtests are generally slightly lower than those obtained by the electricity group. It is also evident that students in the "recommended" group scored higher on all subtests than those in the "not-recommended" group.

It will be noted, too, that the mean score obtained in Electronics for the "recommended" group in auto is slightly higher than that obtained by that group in electricity. This may be explained by the fact that there were several students who had explored auto but not electricity but who nevertheless obtained electronic scores above the mean established for successful electricity students.

The subtest scores obtained by the machine shop students are generally lower than those obtained by either the electricity or auto students. However, it will be noted in Table V that the scores obtained by those not recommended are not lower in every case than those who have

TABLE IV

SUBTEST MEANS AND STANDARD DEVIATIONS

FOR AUTO STUDENTS

SUBTEST	GRAND MEAN N = 40	S. D.	RECOM. MEAN N = 29	NOT RECOM. MEAN N = 11
Electricity	9.02	3.04	9.517	7.27
Electronics	4.52	2.88	4.828	3.727
Mechanics	18.67	4.36	19.103	17.545
Science	8.88	2.95	9.138	8.182
Arithmetic	21.38	4.99	22.172	19.273
Algebra	7.52	3.13	8.207	5.727
Vocabulary	16.07	4.54	16.345	15.364

TABLE V

SUBTEST MEANS AND STANDARD DEVIATIONS FOR

MACHINE SHOP STUDENTS

SUBTEST	GRAND MEAN N = 37	S. D.	RECOM. MEAN N = 30	NOT RECOM. MEAN N = 7
Electricity	8.70	2.44	8.700	8.714
Electronics	3.62	2.35	3.233	5.286
Mechanics	17.65	4.28	17.667	17.571
Science	8.76	2.57	8.700	9.00
Arithmetic	21.30	4.18	21.133	22.000
Algebra	8.14	2.92	8.200	7.857
Vocabulary	16.46	3.67	16.600	15.857

been recommended. The students in the unsuccessful group scored slightly higher than their couterparts on the Electricity, Electronics, Science, and Arithmetic subtests. This may possibly be accounted for by the fact that less differentiation was made between those recommended and those not recommended or that some of those not recommended should have been recommended. There is also the possibility that a lower score may be to a student's advantage in this program as it is presently conducted. Out of a total of thirty-seven students, only seven were not recommended.

Of the four groups it can be observed that the welding students obtained the lowest means on five subtests: Electricity, Mechanics, Arithmetic, Algebra, and Vocabulary. Although the "recommended" group obtained higher scores on all subtests that the "not-recommended" group (Table VI), the differences were not as great as were observed for the auto and electricity students.

In several cases, many of the students who scored low on all tests were nevertheless recommended to continue study in this area. This may partly be accounted for by the fact that in welding one of the major criterions for selection is the possession of certain physical characteristics. Compared to the other areas, less emphasis is placed on the ability to manipulate symbols.

A comparison of the means established on the subtests for each of the four vocational areas is shown in Table VII.

<u>Review of the Analysis of Variance on Subtests for Each Vocational Area</u>

In comparing the means obtained between two groups, it is essential to determine whether or not the difference between the means is tenable

TABLE VI

SUBTEST MEANS AND STANDARD DEVIATIONS FOR

WELDING STUDENTS

SUBTEST	GRAND MEAN N = 38	S. D.	RECOM. MEAN N = 26	NOT RECOM. MEAN N = 12
Electricity	8.29	3.14	8.346	8.167
Electronics	4.18	3.14	4.00	4.583
Mechanics	17.26	4.04	17.885	15.917
Science	8.79	2.97	8.962	8.417
Arithmetic	19.39	5.25	19.846	18.417
Algebra	6.95	3.00	7.423	5.917
Vocabulary	15.42	4.48	16.077	14.00

TABLE VII

COMPARISON OF SUBTEST MEANS FOR RECOMMENDED AND NOT RECOMMENDED GROUPS

		Electricity	Electronics	Mechanics	Science	Arithmetic	Algebra	Vocabulary
Electricity	Recommended	10.286	4.286	19.333	10.429	23.762	9.048	18.048
	Not Recommended	8.235	4.000	15.118	8.941	20.235	6.706	15.059
Automotives	Recommended	9.517	4.828	19.103	9.138	22.172	8.207	16.345
	Not Recommended	7.727	3.727	17.545	8.182	19.273	5.727	15.365
Machine	Recommended	8.700	3.233	17.667	8.700	21.133	8.200	16.600
	Not Recommended	8.714	5.286	17.571	9.000	22.000	7.857	15.857
Welding	Recommended	8.346	4.000	17.885	8.962	19.846	7.423	16.077
	Not Recommended	8.167	4.583	15.917	8.417	18.417	5.917	14.000

difference or whether it is merely a chance variation. Analysis of variance is a method of dividing the variation observed into different parts, each part assignable to a known source, cause, or factor.

Analysis of variance is concerned with two types of variation: between groups variance and within group variance. A comparison of the two types can be made to test mean differences using an F-test. In the following discussion the mean squares attributable to each source are obtained by dividing each of the sums of squares by its respective number of degrees of freedom.

In the current study, the differences between means was found to be most significant between the two groups of electricity students. Interpreting the F-tests shown in Table VIII it can be seen that the differences on the Mechanics, Arithmetic, and Algebra subtests are significant at the .05 level. The mean difference for the Electricity subtest is significant at the .01 level.

Between the two groups in auto, the only variable with sufficient mean difference to show significance at the .05 level was Algebra. Table IX shows that the mean difference found on the Electricity and Arithmetic subtests was next most significant, but only at approximately the .10 level. The differences between means on the Electronics, Mechanics, Science, and Vocabulary subtests were such that they could not be judged as being different than zero.

In Table X the analysis of variance on the subtests for the two groups in machine shop is shown. An examination of the probability of the F-values show that with the exception of Electronics (significant at

TABLE VIII

SUBTEST ANALYSIS OF VARIANCE FOR RECOMMENDED

NOT-RECOMMENDED ELECTRICITY SAMPLE

Variable	Source of Variation	Sum of Squares	df	Mean Square	F	Probability
Electricity	Between	39.497	1	39.497	8.109	0.007*
	Within	175.344	36	4.870		
Electronics	Between	0.766	1	.766	0.100	0.754
	Within	276.85	36	7.674		
Mechanics	Between	166.963	1	166.963	6.953	0.015*
	Within	864.431	36	24.011		
Science	Between	20.784	1	20.784	4.021	.053
	Within	186.084	36	5.169		
Arithmetic	Between	116.842	1	116.842	6.503	0.015*
	Within	646.868	36	17.968		
Algebra	Between	51.518	1	51.518	7.066	0.012*
	Within	775.893	36	7.291		
Vocabulary	Between	83.922	1	83.922	3.894	0.056
	Within	775.893	36	21.552		

*Considered significant at the .05 level or less

TABLE IX

SUBTEST ANALYSIS OF VARIANCE FOR RECOMMENDED

NOT-RECOMMENDED AUTO SAMPLE

Variable	Source of Variation	Sum of Squares	df	Mean Squares	F	Probability
Electricity	Between	25.551	1	25.551	2.827	0.101
	Within	343.423	38	9.037		
Electronics	Between	9.655	1	9.655	1.138	0.293
	Within	322.319	38	8.482		
Mechanics	Between	19.350	1	19.358	0.992	0.326
	Within	741.417	38	19.510		
Science	Between	7.290	1	7.290	.812	0.373
	Within	341.084	38	8.975		
Arithmetic	Between	67.054	1	67.054	2.745	0.106
	Within	928.320	38	24.429		
Algebra	Between	49.034	1	49.034	5.433	0.025*
	Within	342.940	38	9.024		
Vocabulary	Between	7.677	1	7.677	.357	0.554
	Within	817.097	38	21.502		

*Considered significant at the .05 level or less

TABLE X

SUBTEST ANALYSIS OF VARIANCE FOR RECOMMENDED NOT-RECOMMENDED MACHINE SHOP SAMPLE

Variable	Source of Variation	Sum of Squares	df	Mean Squares	F	Probability
Electricity	Between	.001	1	.001	0.000	0.989
	Within	219.728	35	6.277		
Electronics	Between	23.907	1	23.907	4.628	0.038*
	Within	180.795	35	5.165		
Mechanics	Between	.0514	1	.051	0.003	0.959
	Within	244.300	35	19.32		
Science	Between	0.510	1	.510	0.073	0.788
	Within	244.300	35	6.980		
Arithmetic	Between	4.263	1	4.263	0.232	0.633
	Within	643.466	35	18.384		
Algebra	Between	0.667	1	.667	0.074	0.787
	Within	315.657	35	9.018		
Vocabulary	Between	3.132	1	3.132	0.222	0.641
	Within	494.057	35	14.115		

*Considered significant at the .05 level or less

the .03 level) the major part of the variance for the subtests must be attributed to within subjects.

Very few of the mean differences on the subtests between the two groups in welding proved significant. This would suggest that there is practically as much variation within each group as is found between groups. The mean differences for mechanics, algebra and vocabulary proved most significant, but only between the .15 and .20 level. The analysis of the other mean differences are shown in Table XI.

Multiple Stepwise Regression Equation - Analysis of Result

Through use of a regression equation, the scores on one variable may be predicted from the scores of others. Using a stepwise procedure, the predictor variable that accounts for the greatest amount of the variance of the criterion is identified first. In successive stages, the variable accounting for the next greatest amount of the remaining criterion variance is added to the regression equation.

In the present study, regression equations were found for each of the four vocational areas using the assigned marks in each as the dependent variable and the scores obtained on the subtests of the Dailey Technical and Scholastic Test as the independent variables. The correlation coefficients between these are given in Table XII.

To predict a course mark from a subtest score, values are substituted into the equation:

$$P = C_1 + WX_1$$

where P is the predicted mark, C_1 represents the constant, W represents the beta weight assigned and X_1 the subtest score. If more than one

TABLE XI

SUBTEST ANALYSIS OF VARIANCES FOR RECOMMENDED

NOT-RECOMMENDED WELDING SAMPLE

Variable	Source of Variation	Sums of Squares	df	Mean Squares	F	Probability
Electricity	Between	0.264	1	0.264	0.025	0.874
	Within	375.551	36	10.431		
Electronics	Between	2.793	1	2.793	0.271	0.606
	Within	370.916	36	10.303		
Mechanics	Between	31.797	1	31.797	1.948	0.171
	Within	587.570	36	16.321		
Science	Between	2.437	1	2.437	0.263	0.611
	Within	333.878	36	9.274		
Arithmetic	Between	16.777	1	16.777	0.585	0.449
	Within	1032.301	36	28.675		
Algebra	Between	18.631	1	18.631	2.075	0.158
	Within	323.262	36	8.979		
Vocabulary	Between	35.417	1	35.417	1.757	0.193
	Within	725.846	36	20.162		

TABLE XII

CORRELATIONS BETWEEN DEPENDENT VARIABLES AND INDEPENDENT VARIABLES

DAILEY SUBTESTS	ASSIGNED GRADES			
	Auto	Electricity	Machine	Welding
Vocabulary	.411	.227	.211	.198
Electricity	.548	.446	.193	.232
Electronics	.485	.131	-.274	.220
Mechanics	.452	.336	.067	.314
Science	.393	.403	-.032	.163
Arithmetic	.286	.357	.116	.133
Algebra	.272	.476	.197	.293

variable were to be used, the equation would become:

$$P = C_2 + W_1X_1 + W_2X_2 + W_3X_3 \ . \ . \ . + W_nX_n$$

The extent of the error in the predicted scores is measured by the standard error of estimate. This must be considered whenever the correlation between the variables in question is not perfect.

Of the four groups examined, the final grade in auto can be most accurately predicted on the basis of the subtest scores. In examining Table XIII, it can be seen that 39.02 percent of the variance is accounted for. The best single predictor is Electricity, accounting for 30.12 percent of the variance. With the addition of the Electronics and Mechanics subtests, 37.79 percent of the variation in the criterion becomes predictable. The addition of the remaining four variables to the regression equation accounts for only 1.3 percent of the total variance. The best estimate of the auto mark is given by:

Auto mark = 29.02 + 1.38(Ely.) + 1.04(Eln.) + .632(Mech.)

The scores of all forty-five students who had taken auto were considered in arriving at the above equation.

In evaluating the relative contribution of the variables, it must be remembered that at any stage it is not a simple matter of comparing the magnitudes of the regression coefficients since these may vary depending on the variables previously considered.

Table XIV contains the constants and beta weights that would be used in predicting electricity scores from the regression equation. It will be noticed that of the 35.89 percent of the variance accounted for, 32.03 percent of this could be predicted on the basis of the Algebra sub-

TABLE XIII

STEPWISE REGRESSION ANALYSIS FOR AUTO STUDENTS

Step	Variables	Constant	Beta Weight	Accounted Variance
1	Electricity	36.485	2.3716	30.12
2	Electricity	36.403	1.7439	30.12
	Electronics		1.1881	4.51
				34.63
3	Electricity	29.0224	1.3791	30.12
	Electronics		1.0390	4.51
	Mechanics		.6320	3.16
				37.79
4	Electricity	28.1449	1.3641	30.12
	Electronics		.9972	4.51
	Mechanics		.4456	3.16
	Vocabulary		.2992	.56
				38.34
	Total variance accounted for			39.02

TABLE XIV

STEPWISE REGRESSION ANALYSIS FOR ELECTRICITY STUDENTS

Step	Variables	Constant	Beta Weight	Accounted Variance
1	Algebra	38.384	2.0791	22.75
2	Algebra	25.802	1.6089	22.75
	Electricity		1.6865	9.28
				32.03
3	Algebra	22.486	1.5350	22.75
	Electricity		1.1883	9.28
	Science		.9072	2.22
				34.26
4	Algebra	23.748	1.5668	22.75
	Electricity		1.2192	9.28
	Science		1.4677	2.22
	Vocabulary		-0.2486	0.51
				34.76
	Total variance accounted for			35.89

test alone. The addition of the score in Electricity to the equation would account for 9.28 percent of the total variance. Since there are fairly high intercorrelations between the remaining variables (Table II), the addition of these to the regression equation would add little to its predictive ability. Based on the subtest scores of the forty-seven students who had taken electricity, the best estimate of the electricity mark is given by:

Electricity mark = 22.486 + 1.54(Algebra) + 1.189(Ely.) + .907(Sci.)

Referring back to Table XII it is noticed that the correlations between the machine shop and welding scores and the subtest scores are generally lower than was the case for the previous two groups. As a result, less of the variance between the predictors and criterion can be accounted for. It can be seen that of the 25.25 percent of the variance in Machine Shop scores accounted for (Table XV), 7.55 percent of this amount could be predicted using the Electronic subtest. If in addition the Electricity subtest were used, 15.74 percent of the variance could be explained. The addition of the Vocabulary and Science subtests would account for an additional 5.65 percent of the variance. Using the subtest scores of the forty-nine students who had taken machine shop, the best estimate of the machine shop mark is given by:

Machine Shop mark = 53.842 - 2.14(Eln.) + 1.68(Ely.) + 9.57(Vocab.) -1.35(Sci.)

The amount of variance accounted for with the addition of each new variable for the welding group is shown in Table XVI. It can be seen that if only the Mechanics, Algebra, and Arithmetic subtests were used, 15.47 of the total 18.51 variance would be accounted for. The best estimate of

TABLE XV

STEPWISE REGRESSION ANALYSIS FOR

MACHINE SHOP STUDENTS

Step	Variable	Constant	Beta Weight	Accounted Variance
1	Electronics	69.562	-1.6259	7.55
2	Electronics	57.503	-2.1421	7.55
	Electricity		1.6875	8.19
				15.74
3	Electronics	49.457	-2.1420	7.55
	Electricity		1.3654	8.19
	Vocabulary		0.6574	2.35
				18.09
4	Electronics	53.842	-2.1359	7.55
	Electricity		1.6787	8.19
	Vocabulary		0.9565	2.35
	Science		-1.3464	3.30
				21.38
	Total variance accounted for			25.25

TABLE XVI

STEPWISE REGRESSION ANALYSIS FOR

WELDING STUDENTS

Step	Variable	Constant	Beta Weight	Accounted Variance
1	Mechanics	40.408	0.8495	9.89
2	Mechanics	39.103	0.6427	9.89
	Algebra		0.7147	3.60
				13.49
3	Mechanics	41.838	0.7615	9.89
	Algebra		1.1089	3.60
	Arithmetic		-0.3786	1.98
				15.47
4	Mechanics	42.871	0.6553	9.89
	Algebra		1.0964	3.60
	Arithmetic		-0.4240	1.98
	Electronics		0.4099	1.14
				16.61
	Total variance accounted for			18.51

the welding mark is given by:

Welding mark = 41.838 + .762(Mech.) + 1.11(Algebra) - .379(Arith.)

The scores of all forty-two students who had taken welding were considered in arriving at the above equation.

The Discriminant Function - Analysis of Results

The computer program used was designed to obtain an optimum linear weighting system for separation of up to ten a priori defined groups using a maximum of twenty-five variables. In this study those subtests of importance in the regression equation and having the greatest difference between means between the "recommended" and "not-recommended" group were selected as the variables in the discriminant function.

The discriminant function has the general form of

$$v = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots a_nx_n$$

where the x's are the measurements of the different variables and the a's are the optimum weights. The values of "a" may be found by solving a series of simultaneous equations using the difference between means of each variable and the within group variation. The within group deviation is determined using the sums of squares and cross-products. The "v" value represents the discriminant score.

The mean discriminant score for each group was found by applying the discriminant function twice, once by substituting the mean values obtained on the subtests by the successful group and once by substituting the same measures obtained by the unsuccessful group. If homogeneity of variance exits, the midway point between means may be used to represent the critical score. However, the position of the critical score is often

altered when the cost involved in making a wrong decision of classification is being considered. Similarly, in determining the number of variables to be used, a stage may be reached at which the cost involved will not be commensurate with the reduction in the number of wrong classifications.

The variables selected for the discriminant function for the electricity students were Electricity, Mechanics, Science, Arithmetic, and Algebra. The vector weights of each are shown in the discriminant equation:

$$v = .549(\text{Ely.}) + .368(\text{Mech.}) + .003(\text{Sci.}) + .042(\text{Arith.}) + .748(\text{Algebra})$$

Determining the discriminant score for any one individual is a matter of substituting the individual's scores obtained on the subtests in the discriminant function. For example, a student obtaining 12 points on the Electricity subtest, 18 on the Mechanical, 13 on the Science, 28 on the Arithmetic and 8 on the Algebra subtest would have a discriminant score of:

$$v = .549(12) + .368(18) + .003(13) + .042(28) + .748(8)$$

$$v = 19.991$$

To determine what group (recommended or not-recommended) the student is most like, the score "v" would be compared to the midway point (18.307) between the mean discriminant score of each group.

Figure 1 shows a comparison of the teacher's recommendations and those recommendations made on the basis of the discriminant scores. It can be observed that of the twenty-one students in the successful group, the discriminant score of only six fell below the group discriminant mean. This would suggest that on the basis of the aptitudes measured by the

FIGURE 1

COMPARISON OF TEACHER-DISCRIMINANT SCORE

RECOMMENDATIONS FOR ELECTRICITY STUDENTS

	Recommended on Basis of Discriminant Score	Not Recommended on Basis of Discriminant Score
Not Recommended by Teacher	3	14
Recommended by Teacher	15	6

FIGURE 2

COMPARISON OF TEACHER-DISCRIMINANT SCORE

RECOMMENDATIONS FOR AUTO STUDENTS

	Recommended on Basis of Discriminant Score	Not Recommended on Basis of Discriminant Score
Not Recommended by Teacher	3	8
Recommended by Teacher	17	12

test, these six students fell short of the performance demanded for inclusion into that group. It will also be noted that there are three students in the "not-recommended" group whose discriminant scores are greater than the mean for the "recommended" group. Such cases would suggest that other factors are operating in the assessment.

The mean separation between the two groups on the basis of the discriminant equation is significant at the .03 level. The Chi Square value is 12.363, significant at the .05 level with five degrees of freedom.

Less distinction between the two groups in auto could be made than was the case for the electricity students. The computed weights for each of the subtests used are expressed in the following equation:

$$v = .265(\text{Ely.}) + .112(\text{Arith.}) + .957\ (\text{Algebra}).$$

Figure 2 shows that approximately forty percent of the students in the successful group obtained scores somewhat below the mean established for that group. Three of the eleven students in the "not-recommended" group obtained scores higher than the critical score. The mean separation between the groups was found to be significant at the .15 level. The Chi Square value of 5.373 was not significant at the .10 level.

It will be remembered that of the seven subtests used, only the mean difference on the Algebra subtest proved significant at the .05 level. This would suggest that the major criterion used for selection in auto is not being measured to any great extent by the Dailey Technical and Scholastic Test. Whereas in electricity it was found that the scores obtained on the Electricity and Algebra subtests determined to a great extent into which group an individual was placed, no such combination of

variables was found for auto. It is believed that students' interests and attitudes alone towards the program were considered to be of major importance. If such were the case, measures of these traits would have to be included in the discriminant function to increase its effectiveness in suggesting group membership.

Since none of the three subtests used in determining the discriminant function for the welding groups produced any significant variance, the effectiveness of the equation in predicting group membership is greatly limited. As was the case for the auto group on the basis of the sample used, it would appear that the Dailey Technical and Vocational Test lacks sufficient validity to use it as a criterion for the selection of welding students.

If the discriminant equation, $v = .430(\text{Mech.}) + .832(\text{Algebra}) + .349(\text{Vocab.})$ had been used, only fifty percent of those selected for the program would have been recommended on the basis of their discriminant scores. Of the twelve students in the "not-recommended" group three obtained scores greater than the established critical score (Figure 3).

As was the case in the two previous groups, on the basis of the discriminant function, no significant difference was found between those students recommended to continue in machine shop and those students not recommended. The statistical difference between the discriminant function means yielded a probability value of 0.138. Of the three variables used, only the difference in means on the Electronics subtest proved significant. This is reflected in the weighting it received in the discriminant equation $v = .892(\text{Eln.}) + .231(\text{Arith.}) - .386(\text{Vocab.})$. Before any

practical application of this equation could be made, the criterion used for selection in machine shop would have to be more fully identified, measured and computed into the function.

From Figure 4 it can be seen that two thirds of those in the recommended group obtained scores below the critical score. On the basis of their discriminant scores, five of the seven students in the not-recommended group would have been placed in the successful group.

FIGURE 3

COMPARISON OF TEACHER-DISCRIMINANT SCORE

RECOMMENDATIONS FOR WELDING STUDENTS

	Recommended on Basis of Discriminant Score	Not Recommended on Basis of Discriminant Score
Not Recommended by Teacher	3	9
Recommended by Teacher	12	14

FIGURE 4

COMPARISON OF TEACHER-DISCRIMINANT SCORE

RECOMMENDATIONS FOR MACHINE SHOP STUDENTS

	Recommended on Basis of Discriminant Score	Not Recommended on Basis of Discriminant Score
Not Recommended by Teacher	6	1
Recommended by Teacher	9	21

CHAPTER V

CONCLUSION, IMPLICATIONS, AND SUGGESTED RESEARCH

Conclusion

Since there is reason to believe that academic achievement and other types of student growth are relatively independent, evaluations should be made on the basis of multiple criteria. Rather than the transcript of grades now commonly used, appraisals should be made on the basis of a profile of the student's growth and potential since some variables are more important than others to success. Included in such a profile should be the relative contribution of as many measures of student growth as are available.

It was proposed that such an approach is suggested through use of the discriminant function. Using students enrolled in a grade ten exploratory vocational program and their results obtained on the Dailey Technical and Scholastic Test, the present study was designed to show how membership in either the "recommended" or "not-recommended" group in each of four vocational areas could be suggested. In addition, it was suggested that the same information could be used to aid the counsellor in identifying and assisting those students in need of assistance in special subject areas.

In interpreting the results of the study, the size of the sample, the test used and the method of classification employed by the teachers must be considered. It is agreed that the number of students in at least two of the groups hardly permitted the sample to be considered representative of a population. In order to use the discriminant function for

purpose of future classification the sample must be relatively large. This difficulty can only be overcome by accumulating data over a number of years.

In order to determine group membership on the basis of test results, it is of extreme importance that the test have sufficient validity for the program used. To date, no tests of validity for Alberta vocational programs are available for the Dailey Technical and Scholastic Test.

The value of the suggested procedure for selecting students will naturally be determined by the extent to which it will accurately suggest group membership. Before this can be determined, however, criterion for success in each program must be clearly defined and adhered to by teachers. It is felt that this requirement has not been fully met in the programs selected for this study.

Of the four vocational areas examined, it is felt that the requirements outlined above were best met by the electricity group. As a result, the most promising results were obtained for this group. On the basis of the discriminant scores obtained for each individual, seventy-six percent of the total sample would have been placed in the same category as that recommended beforehand by the teacher. There was reason to believe that where there was disagreement, a number of the cases warranted further examination. This could be done using a two-stage testing program and statistical procedures similar to those outlined in this study.

The results obtained for the auto students were somewhat less promising. Of the forty students, sixty percent were placed in the same group as was recommended by the teacher. It is felt that whereas the

Algebra and Electricity subtests differentiated significantly between the electricity groups, no variable or group of variables proved as effective for the auto students.

For the welding and machine shop groups, the apparent lack of validity of the test limited the effectiveness of the discriminant function for predictive purposes. Whereas in the welding group fifty-eight percent of the predictions were in agreement with the teacher's recommendations, there was a disagreement of opinion on seventy-three percent of the machine shop students. Such results could be expected since the analysis of variance indicated that there was little significant difference between the means obtained on the subtests by those recommended and those not recommended in this group. Where such is the case, only those single variables correlated most highly with the criterion or with significant mean difference should be used.

Implications

Despite the lack of a precedent at the high school level and the numerous limitations of the present study, it is nevertheless felt that Alberta vocational guidance counsellors have much to gain through use of the discriminant function. However, its full potential can only be realized after meaningful critical scores have been determined.

To obtain such scores, a number of quantitative measures for two or more matched groups of students about to begin a program of their choice must be obtained. This data might include scores on numerous aptitude tests, interest inventories, tests of manual dexterity, an

appraisal of work values, measures of personality traits, grade nine stanine scores, results in courses from previous grades, past attendance records and any other measures that may contain some predictive value. Ideally, the students would then be permitted to continue in the program without the benefit of guidance based on the recorded observations. Upon completion of the program they would then be classified on the basis of their obtained grades. Results of those students transferring into other programs would also be recorded.

Using methods similar to those employed in this study, critical scores for each desired category of student in each group could then be established. By comparing the effectiveness of the discriminant equations obtained from two groups randomly split within each similar category (cross-validation), the discriminant function for which stability exits in assigning group membership could be determined. Those variables (measures) that proved to be of little value could be deleted and new measures tested for their effectiveness. New students considering the program would first be directed to complete the selected battery of tests. The scores obtained would then be compared to the critical scores previously established.

The uses of such a comparison would be many. By examining the difference between the two scores, prospective students who are apt to experience difficulty could be easily identified. Once identified, reasons leading to this particular choice of program could be discussed, remedial action recommended or alternative programs suggested. Such a procedure, however, should also be validated by experimental manipulation

in order to make sure chance variations are not being capitalized upon.

For those students already in a program and experiencing difficulty, a study of the size of the vector weight products in their discriminant function may prove to be of some value. If such a student, for example, had scored favorably on all dimensions of the function, the counsellor might be led to explore the possibility of some personal problem affecting achievement. Or, a comparison of the student's measured aptitudes and the teacher's assessment may suggest that other factors are operating or influencing the allotment of grades.

In establishing prerequisites for courses, administrators might be advised to compare the discriminant scores obtained by successful graduates in the past to existing policy. It may be, for example, that a particular science course is required for entrance into machine shop yet on the basis of the discriminant function this course may have only a slight bearing on success. Or, if it were found that those students lacking a particular mathematics course were frequently amongst those unsuccessful in a program, a review of the mathematics prerequisite would seem in order.

In conclusion, it must be remembered that use of discriminant analysis is not necessarily being recommended as a replacement for existing procedures of selection and assessment but only as a source of additional information. It is being suggested as one of the multiple considerations required for the profile approach to selection and assessment recommended earlier. It is only then that we can begin to reduce this 'abuse and misuse' of human talent and provide for each student a clearer picture of his abilities so that he may experience a life both

rich to himself and to society.

Suggested Research

The effectiveness of the discriminant function in selection and evaluation procedures is wholly dependent upon the effectiveness of the criteria used in the separation of groups and upon the validity of the variables used to measure these criteria. Improved measures of these two factors will be dependent upon research which relates personal characteristics to performance measures.

Three major areas for research are suggested by the above. First, occupations or vocational programs being considered must be studied in terms of "job elements" (Flanagan, 1963, p. 115) or specific types of behavior which are critical to effective task performance. What behavior really makes a difference between the successful welder and the unsuccessful? between the competent mechanic and the incompetent? Before such questions can be answered the critical tasks involved must be systematically obtained from a set of comprehensive skills involved. The tasks selected must then be described in terms of the psychological nature of the behaviors included in the job element. These job elements must be continuously examined and revised to parallel technological changes and demands.

Where existing psychological tests fail to provide a satisfactory measurement of the job elements under consideration, new ones must be constructed. Particularly at the provincial level, there is an apparent lack of such test research. To date, little attempt has been made to

measure those physical or emotional traits required for success in the various vocational areas. Once available, such tests must be examined to determine the extent to which each is making a unique contribution to the total battery of tests recommended for each area under study.

Flanagan (1963, p. 118) suggests yet a further area for study:

> ... a program of continuous evaluation of alternatives in terms of precise measures of outcomes of existing programs and estimates of outcomes of proposed programs...focussed on model systems developed from appropriate experimental information and implemented through use of a high speed electrical computor.

Such studies would be conducted using the framework of decision theory - the establishing of all costs relating to the use of alternative strategies to determine which strategy will prove most efficient. It is obvious that such studies must be considered at the provincial level and that procedures similar to those outlined in this study could be utilized.

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